2014 TAPPI INTERNATIONAL CONFERENCE ON NANOTECHNOLOGY FOR RENEWABLE MATERIALS
23-26 JUNE 2014 • FAIRMONT HOTEL VANCOUVER
VANCOUVER, BRITISH COLUMBIA CANADA • WWW.TAPPI.ORG/14NANO

Nanocellulose: Technology Applications, and Markets

Presented by:
Jack Miller
Principal Consultant, Market-Intell LLC
Associate Consultant, RISI

TAPPI

Thank you

- Technical advisors:
  - Mike Bilodeau, Director, Process Development Center, University of Maine
  - Wadood Hamad, Principal Scientist, FPInnovations; Adjunct Professor, Depts. Of Chemistry and Chemical BioEngineering, University of British Columbia
  - Robert J Moon, U.S. Forest Service
  - Jeff Youngblood, Associate Professor, School of Materials Engineering, Purdue University

Thank you

- Richard Berry, Chief Technology Officer, V.P., CelluForce Inc.
- Mike Bilodeau, University of Maine
- Jean Bouchard, Principal Scientist, FPInnovations
- Malcolm Brown, University of Texas, Professor
- Ron Crotogino, President and CEO, ArboraNano
- Gilles Dorris, Research Director, FPInnovations
- John Dorgan, Professor of Chemical and Biochemical Engineering, Colorado School of Mines; Co-founder, Polynew Inc.
- Luiz Fernando X Farah, Founder, Cellaxis Biotech
- Robert Evans, Managing Director, Engineered Fibers Technology
- Leonard Fifield, Senior Research Scientist, Pacific Northwest National Laboratory
- Ulla Forsström, Principal Scientist, Energy and Pulp & Paper, VTT Technical Research Centre of Finland
- Anne Savage Franey, President, Bio Vision Technology Enterprises
- Wadood Hamad, Principal Scientist, FPInnovations; Adjunct Professor, University of British Columbia
- Sean Ireland, Manager of New Technologies, Verso Paper Corp.
- Tom Lindström, Senior Research Manager, Innventia
- Terry Knee, Communications Director, FPInnovations
- Greg Maloney, Principal Partner, BioApplied – Innovation Pathways
- Robert Moon, USDA Forest Service, Forest Products Laboratory
- Jean Moreau, CEO, CelluForce Inc.
- World L-S Nieh, National Program Lead, Forest Products, USDA Forest Service
- David Paterson, CEO, Verso Paper Corp.
- Philip Andre Reme, Director, PFI Norway
- Alan Rudie, USDA Forest Service, Forest Products Laboratory
- Kirsi Seppalainen, Communications and Sustainability, Stora Enso Biomaterials,
- Kristin Syverud, Sr. Research Scientist, PFI Norway
- Hiroyuki Yano, Professor, Research Institute for Sustainable Humanosphere (RISH), Kyoto University
- Jeff Youngblood, Associate Professor, School of Materials Engineering, Purdue University

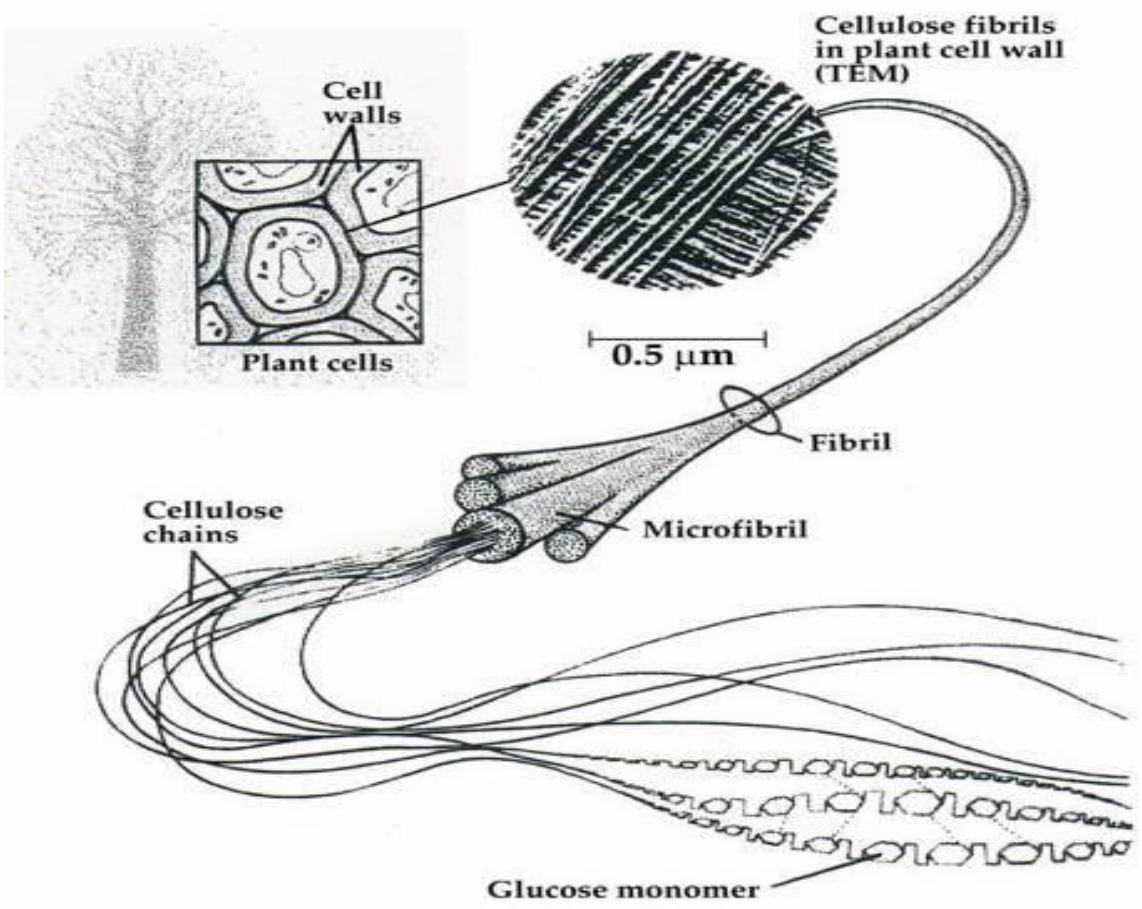
Nano

- Very, very small:
  - 10^{-9} meters
  - Virus: 50 nm
  - Wavelength of light: 400 nm to 700 nm
  - Bacteria: 5,000 nm
  - Human hair: 100,000 nm

Why nano?

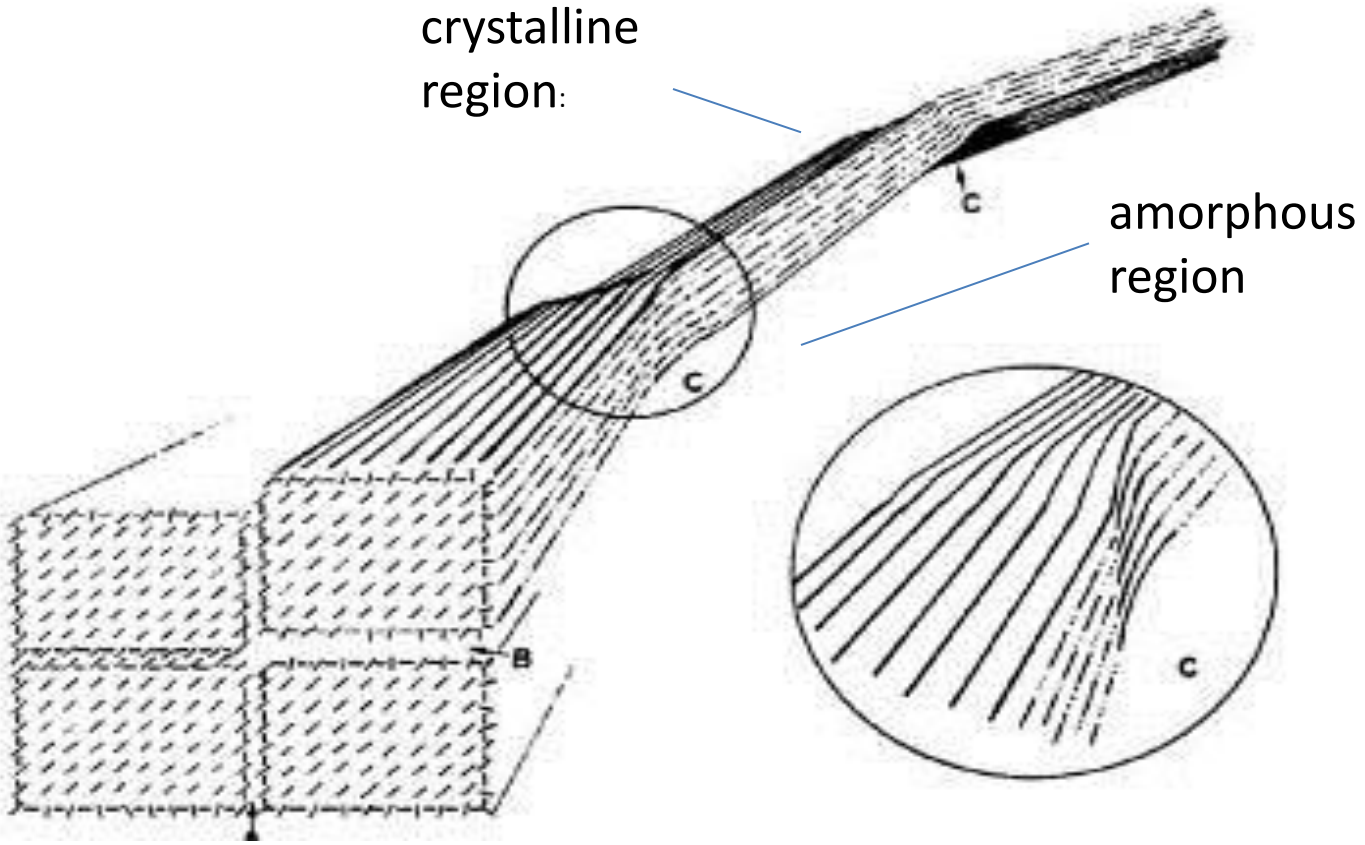
- Very strong
- Large surface area
- Highly reactive
- Defect free
- Unique optical, electrical, magnetic properties

Cellulose



Source: CelluForce

Nanocellulose



Source: CelluForce

Types of nanocellulose

- Cellulose nanofibrils: CNF

  Turbak 1973

- Cellulose nanocrystals: CNC

  Rånby 1951

- Bacterial nanocellulose: BNC

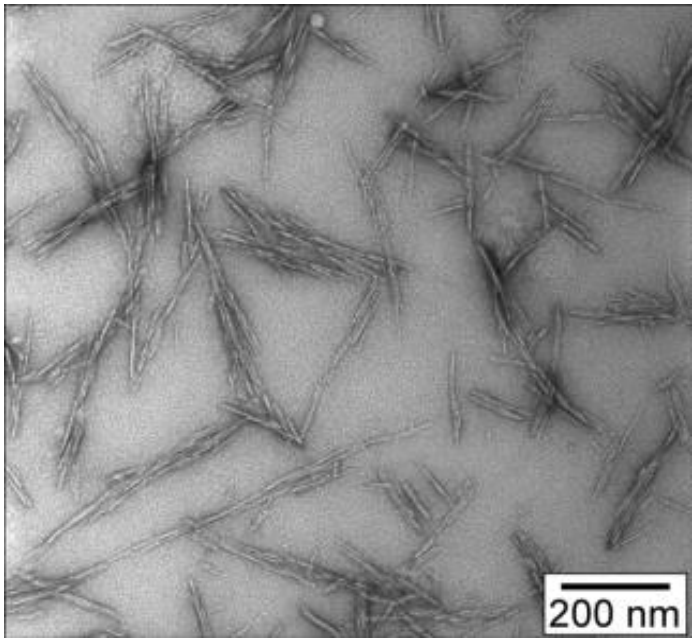
  Brown 1886

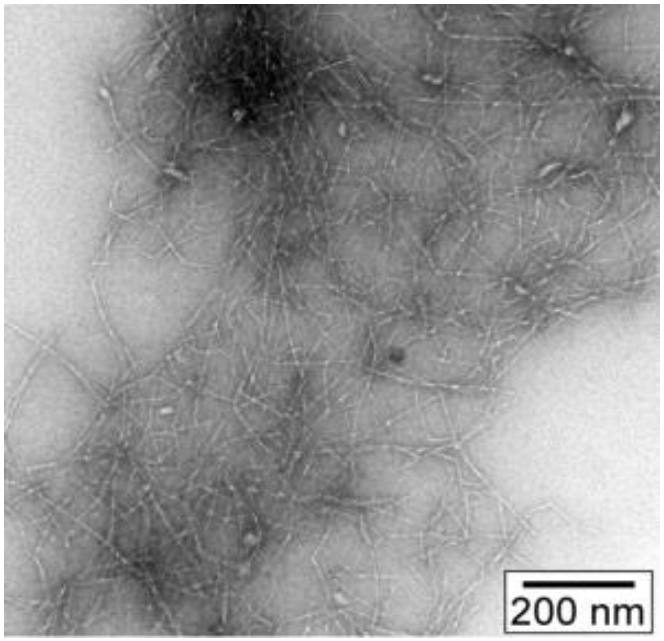
Typical Nanocellulose Characteristics

	Diameter	Length	Crystallinity
Cellulose nanofibril (CNF)	20 - 300 nm	> 2,000 nm	< 70%
Cellulose nanocrystal (CNC)	3 - 5 nm	50 - 500 nm	up to > 90%
Bacterial cellulose	10 - 100 nm	100 to >1000 nm	~70%

Source: Fukuzumi et al, Moon et al, Lee et al, Miao and Hamad

Cellulose Nanocrystals and Cellulose Nanofibrils





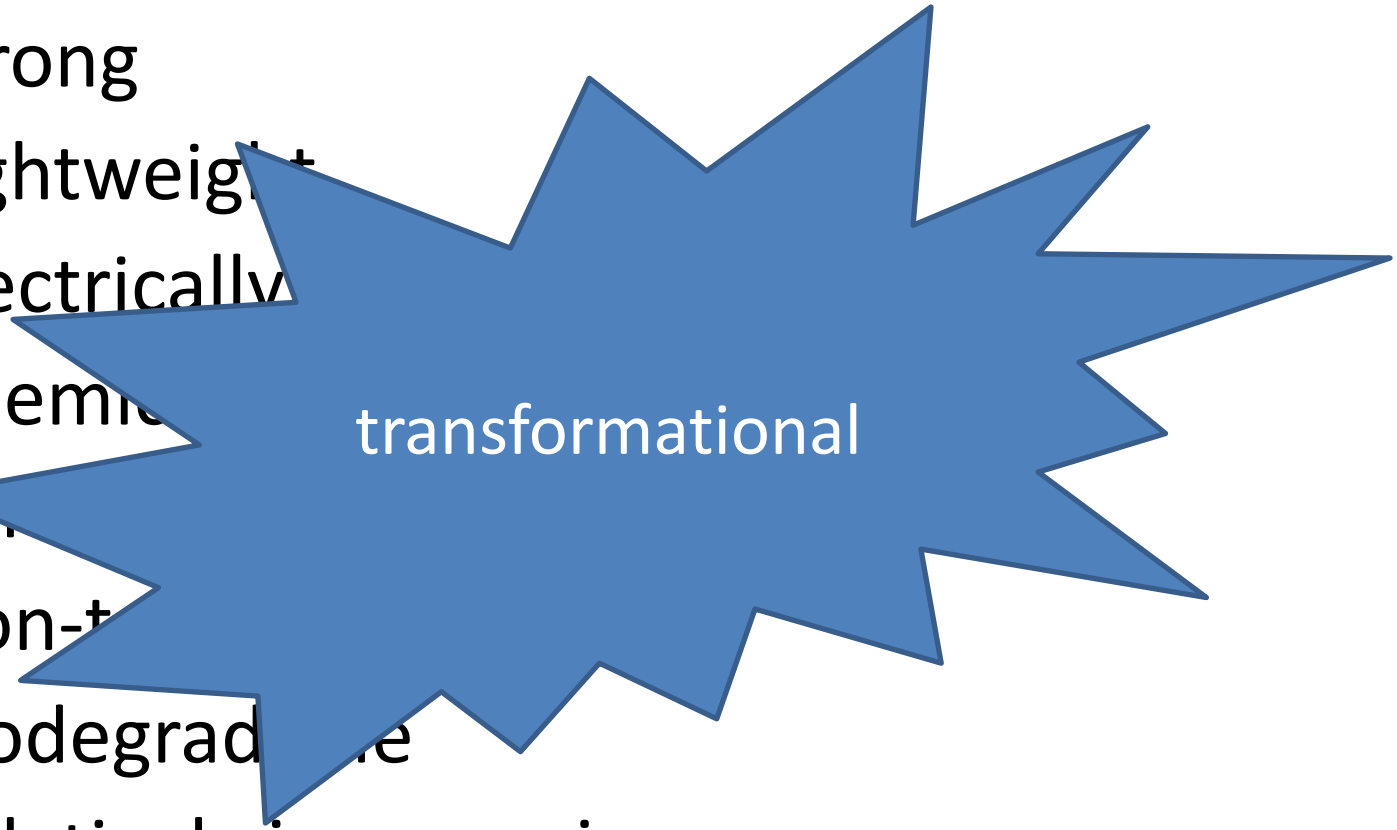
Source: U.S. Forest Products Lab; Purdue University School of Materials Engineering

Why nanocellulose?

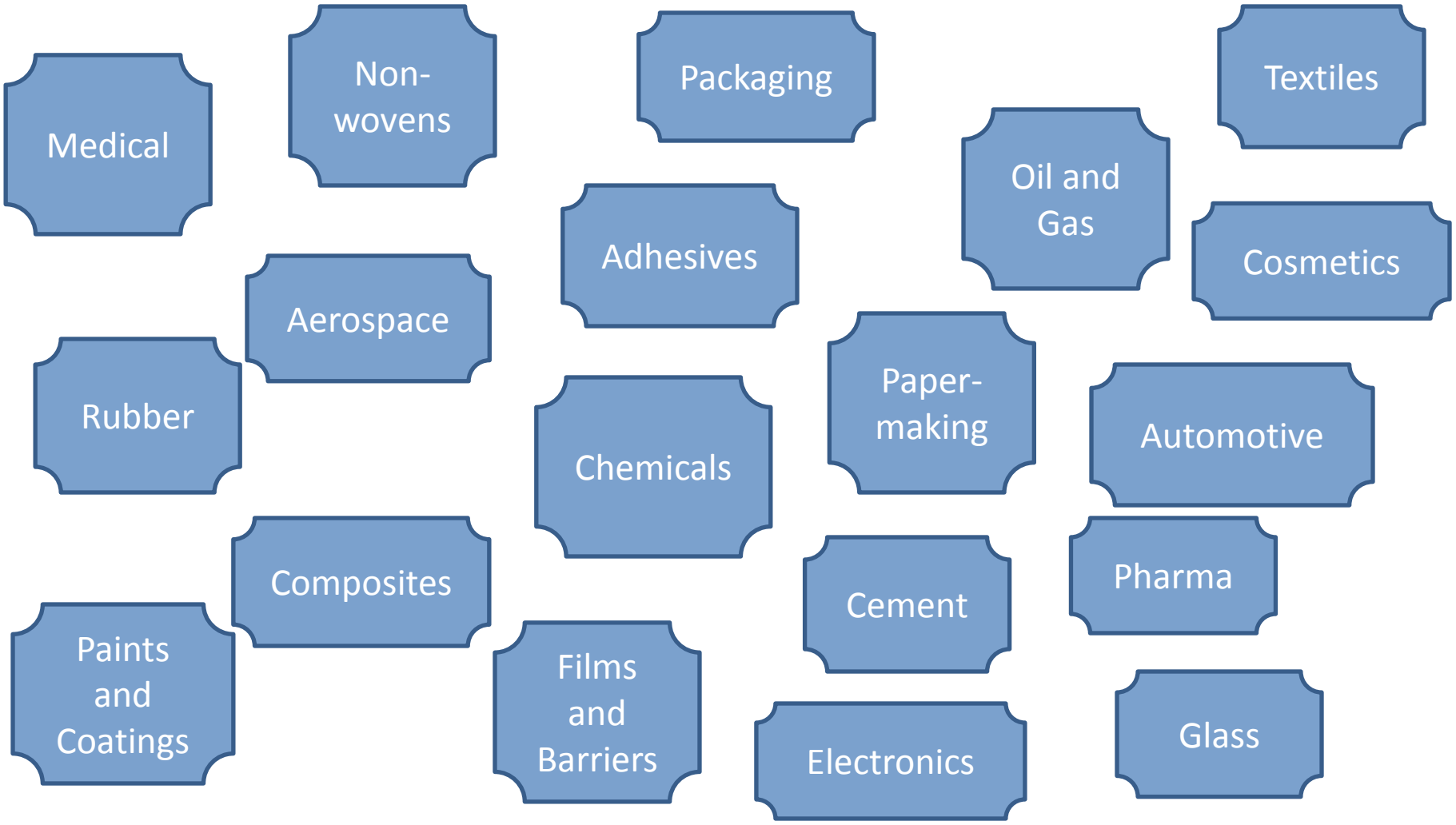
- Strong
- Lightweight
- Electrically charged
- Chemically reactive
- Renewable
- Non-toxic
- Biodegradable
- Relatively inexpensive

Why nanocellulose?

- Strong
- Lightweig
- Electricall
- Chemi
- R
- Non-t
- Biodegrad e
- Relatively inexpensive



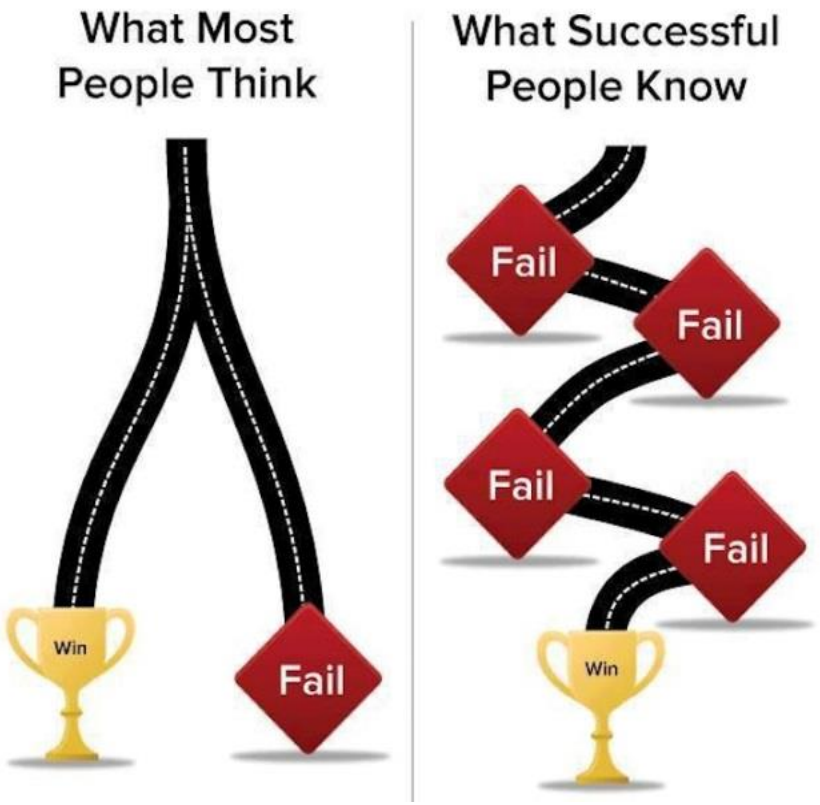
Transform your business



Why now?

- Explosion of research driven by interest in nanotechnology and declining paper markets
- Growing demand for renewable, recyclable, and biodegradable materials
- Nanocellulose makes the leap from lab to market.

We must be patient and resilient



Source: http://e27.co/wp-content/uploads/2013/08/Success.jpg

Cellulose Nanocrystals (CNC) Capacity 2013
(kg per day)

CelluForce	1,000
Alberta Innovates	20
US Forest Service, Forest Products Lab	10
Blue Goose Biorefineries	10
Bio Vision	10
FPInnovations	3
Colorado School of Mines	Lab
Melodea	Lab

Source: RISI, *Nanocellulose: Technology Applications, and Markets*

Cellulose Nanofibrils (CNF) Capacity 2013 (kg/day)

University of Maine, USA	1,000
Nippon Paper, Japan	150
Borregaard, Norway	100
Innventia, Sweden	100
NamiCell, France	100
Oji Paper, Japan	100
FPInnovations, Canada	Pilot
Stora Enso, Finland	Pilot
UPM, Finland	Pilot
Daicel, Japan	Lab
Luleå University of Technology, Sweden	Lab
US Forest Service, Forest Products Laboratory, USA	Lab

Source: RISI, *Nanocellulose: Technology Applications, and Markets*

And…

- CelluComp:
  Curran® “cellulose nanofibres” from food waste materials
- Engineered Fibers Technology:
  “nanofibrillated fibers” from Lyocell
- FPInnovations/Kruger Trois Rivieres:
  “cellulose filaments” 5 tpd
- Imerys:

  FiberLean™ MFC, 3000 tonnes

Bacterial Nanocellulose

Manufacturer	Application
BC Genesis, USA	medical implants
Bowil Biotech, Poland	wound care
Cellaxis Biotech, USA	medical
Cocosong Food Industries, Malaysia	nata de coco
CP Kelco	suspensions
Earthrise, USA	algae
Lohmann & Rauscher, Germany	tissue repair and wound care
PT Sari Segar Husada, Indonesia	nata de coco
Sony, Japan	headphones
Xylos, USA	tissue repair and wound care
Wong Coco Group, Indonesia	nata de coco

Source: RISI, *Nanocellulose: Technology Applications, and Markets*

23 million tonne potential

(000 tonnes)

	Market Size	Potential Loading	Nano Cellulose Potential	Potential @ 5% Market Penetration	CNF Potential	CNC Potential	CNF	CNC
Paper and Paperboard	400,000	5.0%	20,000	1,000	95%	5%	950	10*
Paints and Coatings	40,000	2.0%	800	40	5%	95%	2	38
Composites	9,000	2.0%	180	9	5%	95%	0	9
Films and Barriers	9,670	2.0%	193	10		100%	0	10
Excipients	4,600	2.0%	92	5	10%	90%	0	4
Natural Textiles	34,500	2.0%	690	35		100%	0	35
Manufactured Textiles	56,300	2.0%	1,126	56		100%	0	56
Cement	15,000	0.5%	75	4	5%	95%	0	4
Oil and Gas	17,500	1.0%	175	9	10%	90%	1	8
Nonwovens	7,000	2.0%	140	7		100%	0	7
Adhesives	4,000	2.0%	80	4	5%	95%	0	4
TOTAL			**23,551**	**1,178**			954	184

Source: RISI, *Nanocellulose: Technology Applications, and Markets*

3,625 lbs
25 million tons

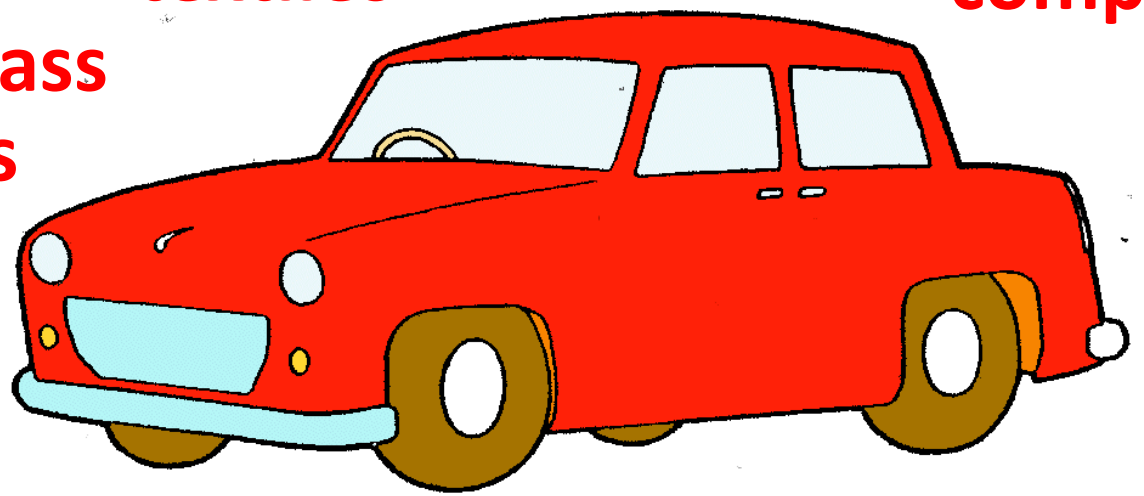
nonwovens

biopolymers

textiles

composites

glass



electronics

paint

metal

plastics

filters

rubber

Leading Suppliers of Bio-based Materials to North American Auto Manufacturers

Ashland	Ohio, USA
Arkema	Pennsylvania, USA
BASF	Michigan, USA
Bayer Material Science	Pennsylvania, USA
BioAmber	Pennsylvania, USA
Canadian General Tower	Ontario, Canada
CelluForce	Quebec, Canada
Cereplast	Indiana, USA
Cooper Standard	Michigan, USA
Denso	Michigan, USA
Dow	Michigan, USA
DSM	Netherlands, USA
DuPont	Delaware, USA
Durafibre	Saskatchewan, Canada
Federal Mogul	Michigan, USA
GreenCore Composites	Ontario, Canada
International Automotive Components	Michigan, USA
Johnson Controls	Wisconsin, USA
Lear	Michigan, USA
Magna International	Ontario, Canada
Mitsubishi Plastics	Japan
NatureWorks	Minnesota, USA
PolyOne	Ohio, USA
SABIC Innovative Plastics	Michigan, USA
Schulman	Ohio, USA
Valle Foam	Ohio, USA
Visteon	Michigan, USA
Woodbridge Group	Michigan, USA

Nanocellulose to 2025
(000 tonnes)

	2013	2020	2025
CNF	10	100	400
CNC	< 1	8	50
BNC	< 1	< 1	< 1

Source: RISI, *Nanocellulose: Technology Applications, and Markets*

Transformation takes time

Source: RISI, *Nanocellulose: Technology Applications, and Markets*

Timeline

- **PLA**

Carothers 1932

Patent 1954

NatureWorks formed 1997

Plant startup 2002

Second plant 2016

- **CNC**

Rånby 1951

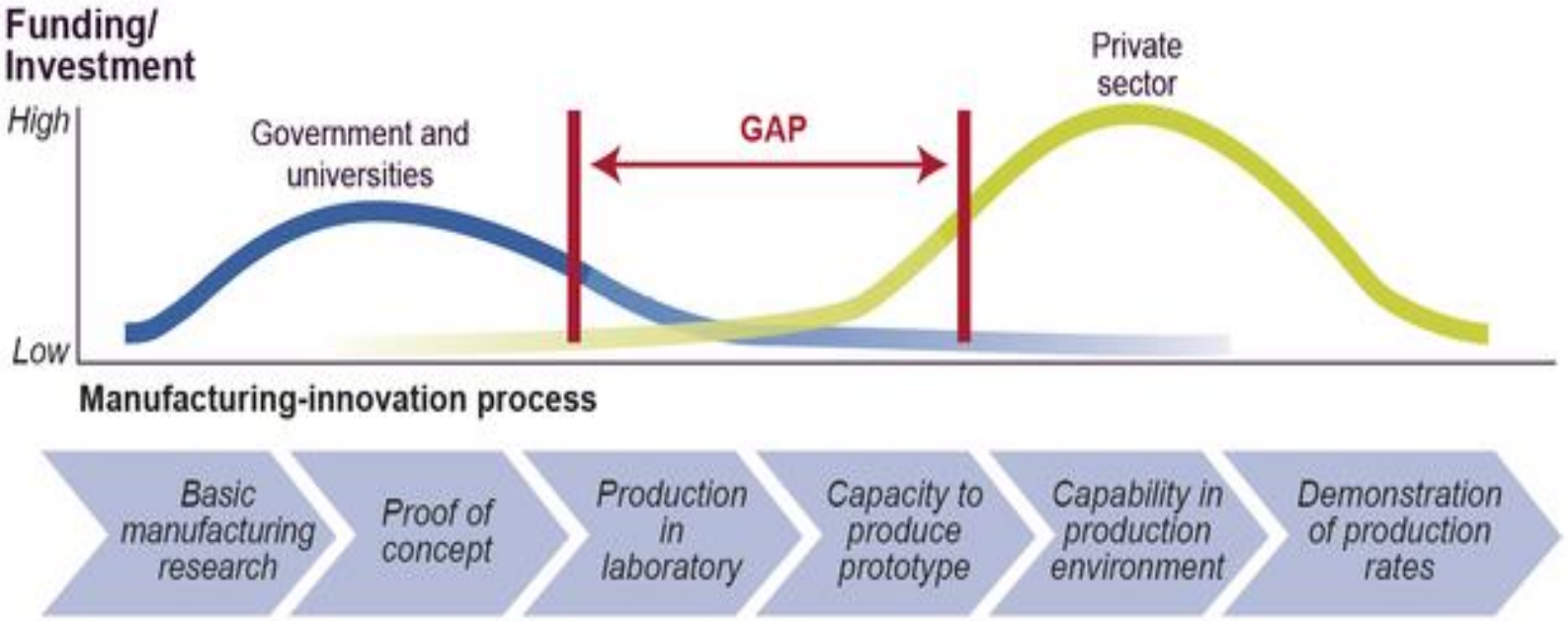
Patent 1997

CelluForce formed 2010

Plant startup 2012

Second plant ????

Investment Gap



Source: GAO

“We always overestimate the change that will occur in the next two years and underestimate the change that will occur in the next ten.”

--Bill Gates

Thank you

PRESENTED BY

Jack Miller
Principal Consultant, Market-Intell LLC
Associate Consultant, RISI
jack.miller@market-intell.com
http://www.risi.com/nanocellulose